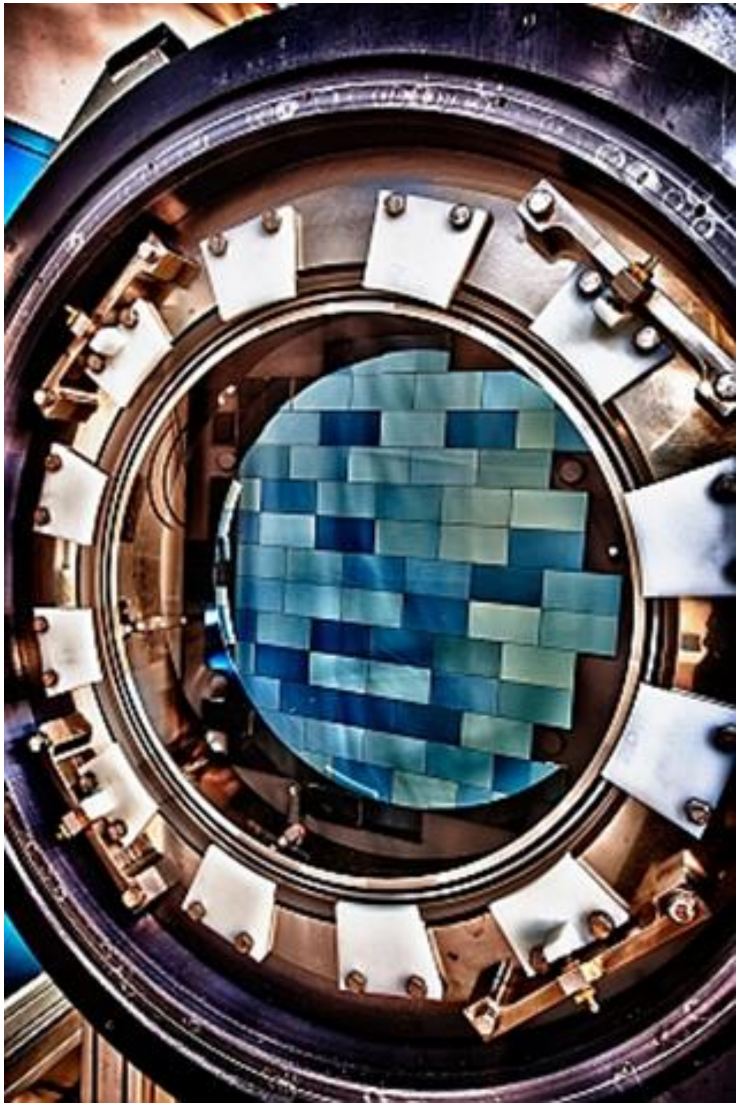
DOE High Energy Physics (HEP) Cosmic Frontier (CF)

report to the

National Academy of Sciences Committee on "Reviewing the Progress Toward the Decadal Survey Vision in New Worlds, New Horizons in Astronomy and Astrophysics"



8 October 2015

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Outline

Office of Science (SC), HEP, CF Program

- Model, Mission, Guidance & Recommendations

HEP BUDGETS

COSMIC FRONTIER

- Budget
- Program Status
- Future planning

DOE Office of Science (SC) Program

The DOE/SC is the lead federal agency supporting fundamental scientific research for energy and the Nation's largest supporter of basic research in the physical sciences.

SC is a part of a mission agency

- Provides science leadership & support to enable significant advances in specific science areas
- Develops and supports a portfolio of selected facilities & experiments to obtain the science
- Laboratory System
  - Comprehensive resources to design, build, operate selected facilities & projects
  - Infrastructure, including computing facilities (NERSC, SCiDAC program etc)
- Interagency & International partnerships as needed to leverage additional science & expertise

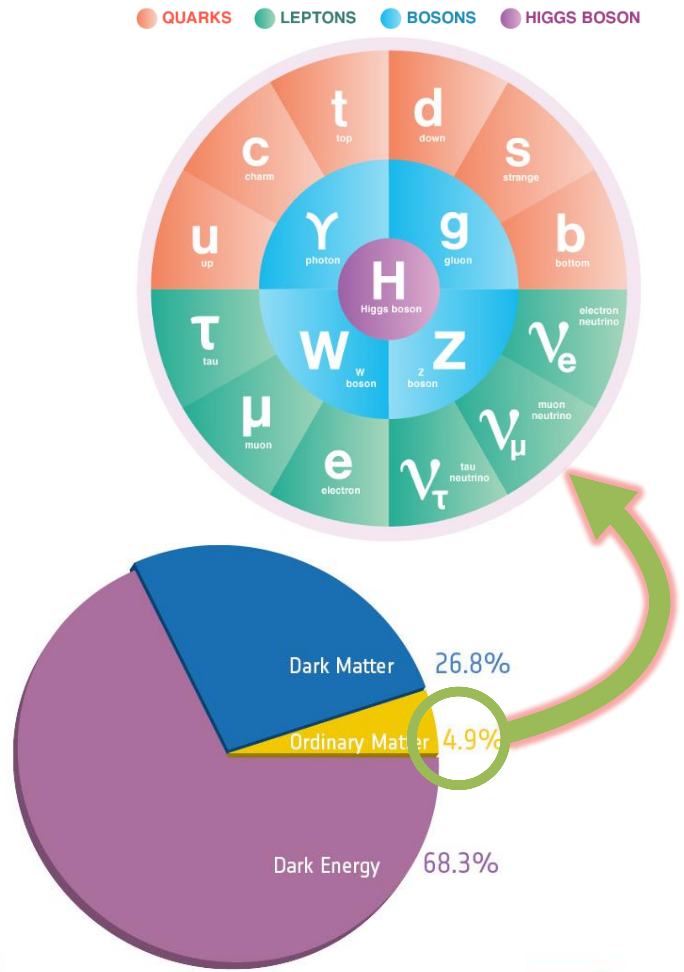
Mission Emphasis translates into how the SC Programs are planned & managed:

- Extensive use of peer review & federal advisory committees to develop general directions for research investments, to identify priorities and select the very best scientific proposals to support.
  - Strategic planning process with community input to develop a plan for science drivers and a portfolio facilities and experiments to obtain significant advances in these science areas.
  - Program Offices follow the strategic plan to carry out a specific portfolio of selected facilities & experiments to obtain the science.

The Office High Energy Physics (HEP) Program Mission

…is to understand how the universe works at its most fundamental level:

- Discover the most elementary constituents of matter and energy
- Probe the interactions between them
- Explore the basic nature of space and time



➔HEP fulfills its mission by:

- Building **projects** that enable discovery science
- Operating **facilities** that provide the capability to perform discovery science
- Supporting a balanced **research** program that produces discovery science

➔HEP is following the P5 (2014) strategic plan in developing and executing the program.

HEP Program Model

➔The Mission Emphasis translates in to how the HEP Program is managed:

- **Planning Program**
  - Community advice used in process to develop a strategic plan for science drivers and facilities and experiments to obtain significant advances in these science areas.

- **Implementation**
  - HEP uses the strategic plan to develop and support a specific portfolio of selected facilities & experiments to obtain the science.
  - Plan stages of experiments for ever-increasing precision
  - Complementary approaches using different technologies & methods
  - Long-term support for our responsibilities in designing, building and operating projects
  - Collaboration/Teamwork: Encourage and support scientific teams with expertise in required areas to participate in all phases of a project/experiment, in order to produce the best possible science results

HEP Program Guidance

<u>FACA panels & subpanels provide official advice:</u>

- **High Energy Physics Advisory Panel (HEPAP)**
    - Reports to DOE and NSF
    - <u>Provides the primary advice for the program</u>
  - Subpanels for detailed studies (e.g. Particle Astrophysics Science Assessment Group "PASAG", Particle Physics Project Prioritization Panel ("P5")

  ➔Strategic Program Planning

    - HEPAP unanimously approved a new long term strategic planning report from the "P5" subpanel in May 2014

- **Astronomy and Astrophysics Advisory Committee (AAAC)**
  - Reports to NASA, NSF and DOE on areas of overlap

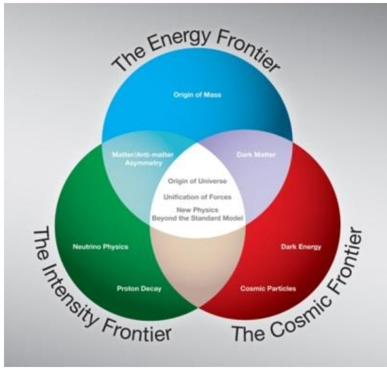
<u>National Academy of Sciences</u>

- Reports: New Worlds New Horizons (2010), "Mid-decade review" in astronomy/astrophysics (starts late 2015)
- Ongoing committees: Board on Physics & Astronomy (BPA), Committee on Astronomy & Astrophysics (CAA)

<u>Other</u>: community science studies, reviews, DPF input, etc. Examples:

- Dark Energy science group "Rocky-III" - Science case for a HEP dark energy program developed by a task force at HEP request (Rocky Kolb, chair) – 2012 report led to moving forward on BigBOSS/DESI
- Snowmass community science study (2013) – provided input for the 2014 P5 study.

HEP Program Guidance 2008-2009



➔2008 HEPAP Particle Physics Project Prioritization Panel (P5) Strategic Plan

Progress in achieving the goals of particle physics requires advancements at the

- Energy Frontier - Exploit the capabilities of the Tevatron and LHC at the to make discoveries
- Intensity Frontier - Implement a world-class program; neutrino program at Fermilab as flagship
- Cosmic Frontier - Address compelling high-impact scientific opportunities with an emphasis on dark energy and matter
  - Joint Dark Energy Mission (JDEM) in collaboration with NASA
  - Large Synoptic Survey Telescope (LSST) in collaboration with NSF
  - Direct dark matter search experiments
  - Develop a more detailed plan (PASAG)
- Develop accelerator technologies needed by Nation & for U.S. leadership role in particle physics

➔2009 HEPAP Particle Astrophysics Science Advisory Group (PASAG)

- To further define the HEP "particle astrophysics" program
- Recommended an optimized program over the next 10 years in 4 funding scenarios
- Defined Prioritization Criteria for Contributions to Particle Astrophysics Projects
  - Science addressed by the project necessary (significant step towards HEP goals)
  - Particle physicist participation necessary (significant value added/feasibility)
  - Scale matters (particularly at boundary between particle physics and astrophysics)

Recommendations:

Dark matter & dark energy remain the highest priorities

- Continue working with NASA on concepts for a Joint Dark Energy Mission (JDEM)
- Continue development of LSST camera concept; support R&D
- Recommended the High Altitude Water Cherenkov (HAWC) project with NSF

Guidance from Astro2010 “New Worlds New Horizons” Report (August 2010)

Budgetary scenarios

- **Levels given by DOE –** constant with inflation (FY10$)
- **Level used by NWNH for recommendations:**
  DOE – doubling trajectory (doubling over 10 years from FY10, assume 4% over inflation)

NWNH recommended a coordinated ground/space-based Dark Energy program

- Highest priority in space: WFIRST (DOE, NASA)
- Highest priority on ground: LSST (DOE, NSF)

Specific Recommendations to DOE :

- **The optimistic funding profile allows investment in:**
  - LSST – DOE should partner with NSF
  - WFIRST – DOE should contribute (note that this is not a dedicated dark energy mission)
- **At lower funding level:**
  - LSST is recommended as the priority because DOE role is critical

- **Other identified opportunities:**
  - **Contributions to NSF mid-scale experiments (2nd priority in ground-based)** e.g. BigBOSS, CMB, HAWC experiments, etc.
  - **NSF & DOE contribute as a minor partner (4th priority in ground-based)** to a European-led AGIS/CTA ground-based gamma-ray observatory
  - **CMB:** technology program to advance detection techniques”
  - Joint Agency competed **Research Networks in Theoretical and Computational Astrophysics program** ($2M/year DOE)

Astro2010 "NWNH" (2010) & PASAG (2009)
DOE HEP Comments & Path Forward (as of end of 2010)

Comments

Budgetary scenarios: Current funding projections tend towards the lower funding amounts & don't have the same profile assumed by NWNH

DOE OHEP Objectives:

- Contributions to select, high impact experiments with discovery potential
  - that address HEP goals & where DOE HEP researchers & investments can play a significant role in and make significant contributions (PASAG recommended criteria)
- Achieve earliest, best, and most cost-effective U.S. dark energy and dark matter science results
- Partnerships with NASA and NSF and international collaborators as appropriate

Priorities

- Dark matter – direct detection experiments are a priority (not part of Astro2010 study)
- Maintain a leading U.S. role in dark energy research (Astro2010 recommendation)
- Other opportunities for contribution as funding permits

Path Forward

Follow HEPAP (PASAG) guidance on Dark Matter – dark matter experiments with NSF Physics

Follow PASAG/Astro2010-NWNH guidance on Dark Energy

- Work with NSF-Astronomy to move forward on LSST; match up our project planning, funding & schedules as needed
- DOE will consider other proposals and partnerships as appropriate (e.g. BigBOSS)

Follow PASAG/Astro2010-NWNH guidance in other areas

- Cosmic-ray, Gamma-ray, CMB

- **NWNH CMB technology recommendation -** HEP supports advanced detector and readout technology at national labs and universities.
- **NWNH Theory & Computation Research Network recommendation:** HEP currently supports a competed Theory Program that covers all HEP-related studies, including computational cosmology, and cosmological modelling, simulations and theory studies; Do not plan a separate program in this area.

Community Task Force report - 2012

➔2012 “Rocky-III”– HEP community dark energy science plan

- HEP requested task force “Rocky-III” to pro-actively develop a balanced, robust dark energy HEP program - With near term and low cost options, using multiple methods
- The Aug. 2012 report identified key missing components and opportunities in progressing to a stage IV program with multiple methods:
  - *There is compelling case for an advanced wide-field spectroscopic survey, which would enable dark-energy information at the Stage IV level through the techniques of Baryon Acoustic Oscillations and Redshift Space Distortions. A spectroscopic survey would produce Important dark-energy science results in the period between the completion of the Stage III Dark Energy Survey (DES) photometric project and the arrival of results from the Stage IV LSST photometric project.*
- Critical Decision 0 (CD-0) for Mid-scale **Dark Energy Spectroscopic Instrument (DESI)** experiment signed 9/18/12; then began discussing with NSF about opportunities & models.

Snowmass Science opportunities report (2013) →
P5 "Strategic Plan for US Particle Physics in the Global Context" (2014)

In recent years, we have new results that point the way forward:
Discovery of the Higgs, Measurement of the "small" neutrino mixing angle (θ_{13}), Rapid advances in Dark Matter direct detection; precision Dark Energy studies; glimpses of inflation in the early universe, advances in accelerator technologies
→HEP needs a compelling & executable strategic plan, with community behind it
- Community Science Opportunities described in **2013 Snowmass report -** provided input to P5

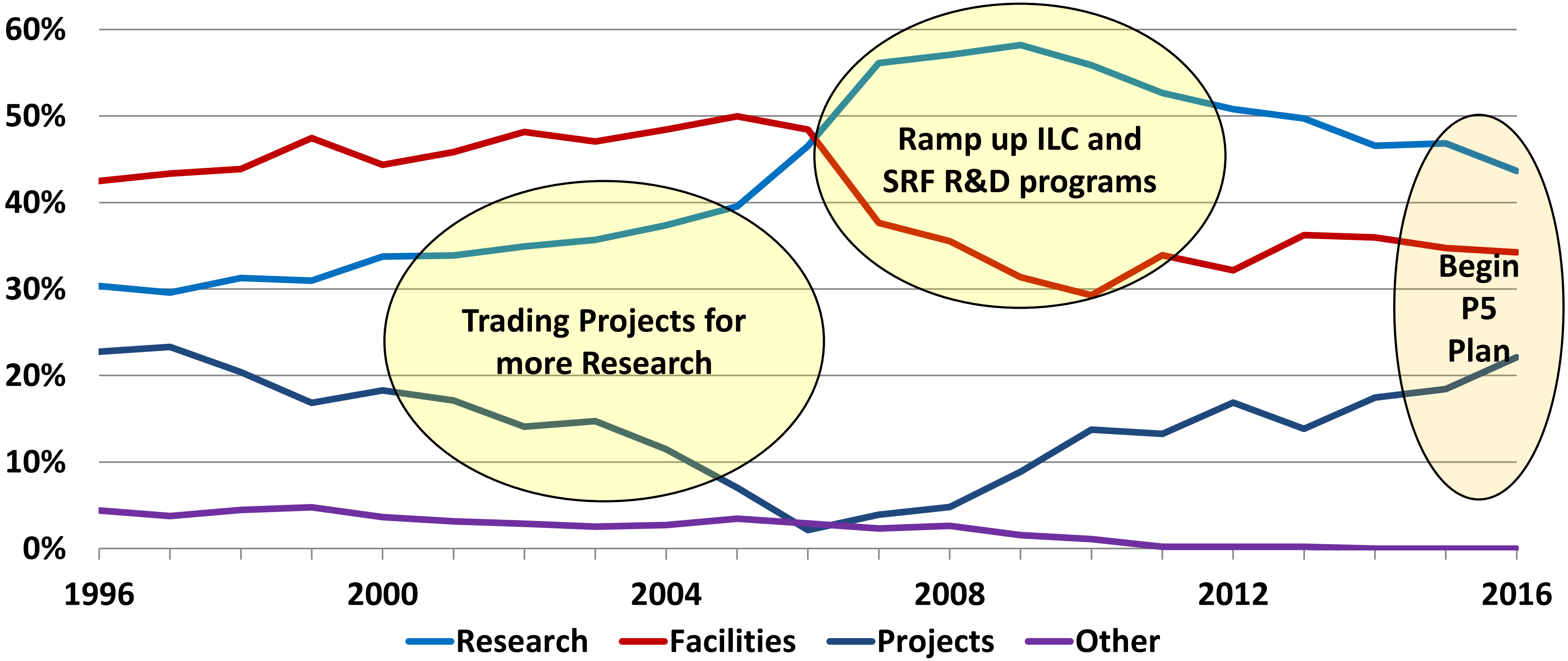
P5 study assessed and prioritized HEP projects over a 20-year timeframe within reasonable budget assumptions and position the U.S. to a be a leader in some (but not all) areas of HEP.
- **P5 plan (approved by HEPAP in May 2014) is a compelling, unified vision for HEP – 5 science drivers**
  - **Use the Higgs boson as a new tool for discovery**
  - **Pursue the physics associated with neutrino mass**
  - **Identify the new physics of dark matter**
  - **Understand cosmic acceleration: dark energy and inflation**
  - **Explore the unknown: new particles, interactions, and physical principles**

HEP Program is following the P5 Strategic Plan!

P5 provided criteria for HEP to use to develop the program & determine which projects, and at what level, to invest in.
- **Recommended balanced program of time-phased, projects of different scales, science goals, on- & off-shore, short term and longer-term**
- **Highest priority major projects are Large Hadron Collider (LHC) detector (ATLAS, CMS) & High Luminosity machine upgrades in the near-term; Long Baseline Neutrino Facility (LBNF; aka LBNE) in the mid-term; LBNF will be the first truly international experiment from the start hosted by the US**
- **Cosmic Frontier: Advance our understanding of dark matter and dark energy**
  - Highest priorities are continuing studies & development of new capabilities in direct dark matter detection & dark energy, with near term projects ready to go
  - Lay the ground work for future projects → including in CMB

HEP - Funding Trends by Fiscal Year

(FY 2016 shows President's Request)



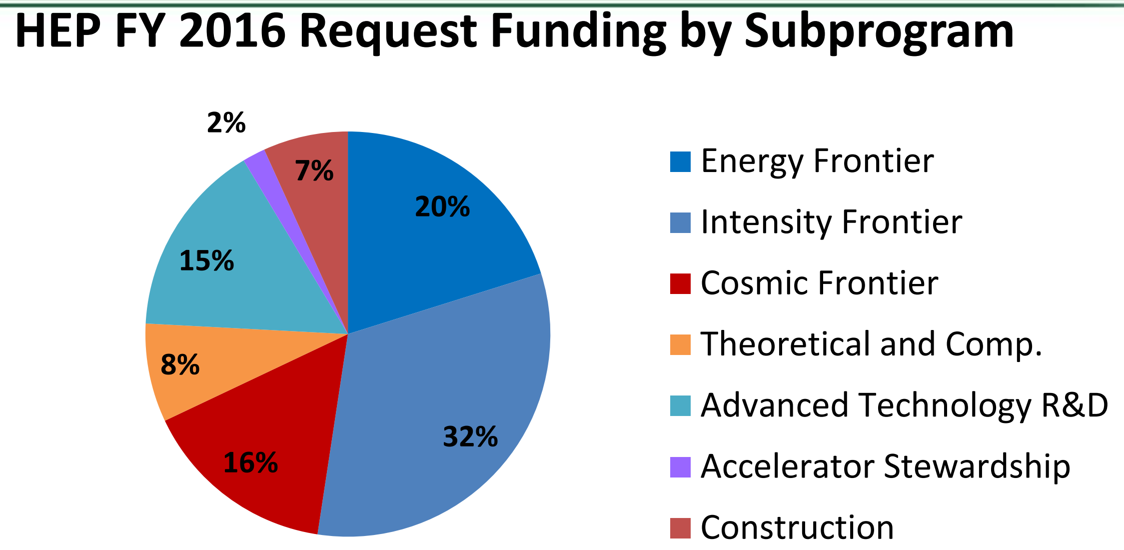
- **P5 report recommendation suggests increasing the project budget fraction to 20%–25%**
  - "Addressing the [science] Drivers in the coming and subsequent decades requires renewed investment in projects."
- **P5 report strategy has informed the HEP request in the FY 2016 DOE budget**

FY 2014-2016 HEP Program - Budget Status

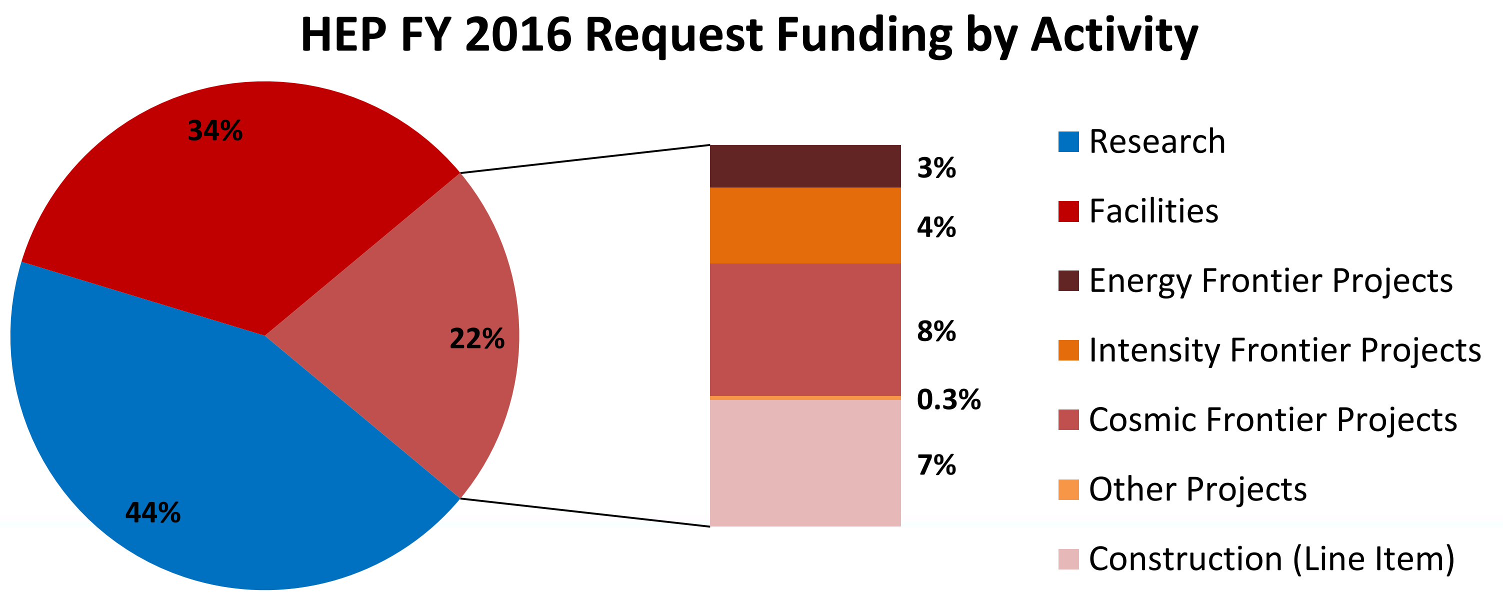
HEP Budget History ($K)	FY 2014 Request	FY 2014 Actual	FY 2015 Request	FY 2015 Enacted	FY 2016 Request	FY 2016 House Mark (~ 5/6/15)	FY 2016 Senate Mark (~ 5/27/15)
Energy Frontier	154,687	152,386	153,639	147,584	154,555		
Intensity Frontier	271,043	250,987	251,245	264,224	247,196		
Cosmic Frontier	**99,080**	**96,927**	**101,245**	**106,870**	**119,325**		
Theoretical and Computational	62,870	64,275	58,850	59,274	60,317		
Advanced Technology R&D	122,453	150,270	114,242	120,254	115,369		
Accelerator Stewardship	9,931	9,075	*19,184*	*10,000*	*14,000*		
Construction	35,000	51,000	25,000	37,000	56,100		
Total	755,064	774,920	723,405	745,206	766,862		
SBIR/STTR*	21,457	0	20,595	20,794	21,138		
HEP Total	**776,521**	**774,920**	**744,000**	**766,000**	**788,000**	**776,000**	**788,100**
Office of Science Total	5,152,700		5,111,155	5,067,738	5,339,800	5,100,000	5,143,900

*FY14 SBIR/STTR was ~ $21M, so FY2014 actual was ~ $796M.

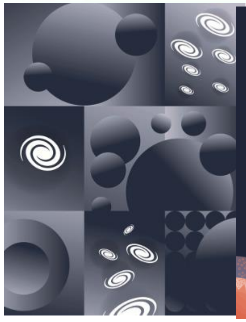
FY 2016 HEP Budget Request Overview



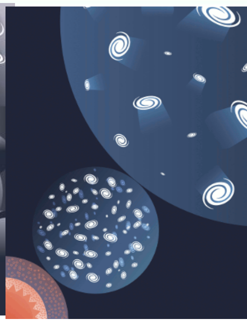
HEP FY16 Request is $788M



Cosmic Frontier Program

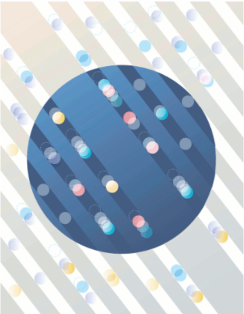


Dark Matter



Cosmic Acceleration

Explore the Unknown



Neutrino Mass

Cosmic Frontier: Through ground-based telescopes, space missions, and deep underground detectors, research at the cosmic frontier aims to explore dark energy and dark matter, which together comprise approximately 95% of the universe.

Program thrusts:

- Study the nature of **Dark Energy**
- Direct Detection searches for **Dark Matter** particles
- **Cosmic-ray & Gamma-ray studi**es – particle properties, high energy acceleration mechanisms, indirect searches for dark matter particles
- **CMB –** current minor efforts planned to expand
- **Other**: computational cosmology; + related Theory, Detector development, computational, etc.

Status

- ➢ **Continue development near term projects recommended by P5.**
- ➢ **Planning activities to support P5 recommendations later in the decade.**

May 2014 P5 Report – Cosmic Frontier Recommendations

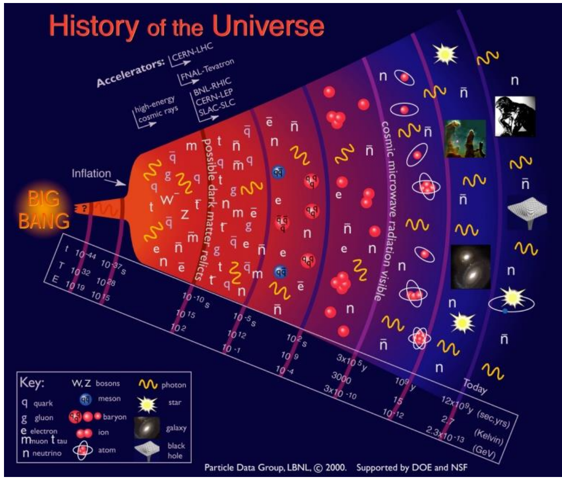
P5 strategic plan: 5 science drivers

	Energy Frontier	Intensity Frontier	Cosmic Frontier
Higgs Boson	●		
Neutrino Mass		●	●
Dark Matter	●	●	●
Cosmic Acceleration			●
Explore the Unknown	●	●	●

P5 report recommendations addressed to the Cosmic Frontier ➔

- **Dark Energy**
  - Build DESI as a major step forward in dark energy science
  - Complete LSST as planned
- **Dark Matter**
  - Proceed immediately with a broad second-generation (G2) dark matter direct detection program with capabilities described in t
    - Invest in this program at a level significantly above that called for in the 2012 joint agency announcement of opportunity
  - Support one or more third-generation (G3) direct detection experiments
    - Guide G3 by the results of the preceding (G1, G2) searches
    - Seek a globally complementary program and increased international partnership in G3 experiments (DM-G3 Project is in the P5 plan later in the decade.)
- **Cosmic Microwave Background (CMB)**
  - Support CMB experiments as part of the core particle physics program
  - The multidisciplinary nature of the science warrants continued multi-agency support (CMB-S4 Project is in the P5 plan later in the decade.)
- **Cosmic Rays and Gamma Rays**
  - Invest in CTA only if the critical NSF Astronomy funding can be obtained
    - CTA has a broad science reach that transcends fields, with the dark matter detection capabilities of direct importance to particle physics; Using P5 Criteria, a de-scoped US component should be shared by NSF-AST, NSF-PHY and DOE.

Cosmic Frontier - Program Model, Development, Considerations



Science Mission-driven:

We develop and support a specific portfolio of projects to obtain significant advances in science results.

Build Program following the P5 Plan & P5 Criteria with

- Staged implementation & results
- Mix of smaller, larger projects
- Using multiple methods and technologies as needed
- Balance between thrusts
- Balance of speculative efforts with ones that guarantee results

Use P5 Criteria when considering which Projects/Experiments to support & at what funding level:

- Science goals and how it will address DOE-HEP goals?
  - Experiments which are directly-aligned or partially aligned with science goals of interest to the HEP program
- What does HEP Community bring to the experiment?
  - Need to bring unique, visible, leadership contributions, especially if it's an area usually supported by another agency. Typically this is expertise in developing & delivering state-of-the art instrumentation, "big data" computing facilities and expertise, and having a cohesive science collaboration to carry out all phases of the project/experiment and deliver precision results.

Other considerations

- Are HEP project contributions in line with % of the project relevant to our science goals?
- Are roles and responsibilities on the project in line with our contributions?
- Partnerships; Domestic vs off-shore
- Don't "mayonnaise" funds all over many small efforts.

Cosmic Frontier Program – Details of Model, Development, Contributions, & Considerations

Details & Model for Building Program

- Make significant, coherent contributions to facilities/experiments selected for the program at a level commensurate with expected science return on HEP physics goals
- Support an HEP-style science collaboration in all stages, including coordinated data analysis to get the best possible science results
- Form partnerships or use other agency's facilities when needed (e.g. telescopes)
- For facilities with broader science program (e.g. LSST) than the interests of the HEP program
  - we make project contributions at appropriate level &support research efforts for our science interests

HEP Contributions:

➔HEP brings significant contributions and new capabilities "to the table" in projects that serve multiple science communities, (e.g Astronomy & HEP Community) including:

- Expertise and delivery of next-generation, large instrumentation (e.g. DECam, LSST-camera, DESI)
- Laboratory infrastructure to design, build and manage projects
- Coordinated computing facilities, simulations and analysis efforts to support the projects and data
- Tradition of large, coordinated science collaboration to carry out all phases of the project/experiment and deliver precision results.

→ Provides significant impacts & resources to the astronomy community.

Cosmic Frontier
Interagency & International considerations

Interagency projects: can provide necessary or additional resources leading to opportunities for increased science.

- Depending on science, project, contribution, agency considerations it may make sense to partner, provide facilities, and/or coordinate efforts.
  - Partnerships between agencies and other offices within agencies (co-fund/manage the construction/operations)
  - Use of other agency's facilities (e.g. install/operate instrument on a telescope)
- While all government agencies follow the same rules, there are differences in the detailed agency and community practices which need to be taken into account to ensure data and science analysis return
  - Processes for planning/deciding on projects, managing/funding projects, funding research, etc
  - HEP emphasis on collaboration for coordinated science planning & analysis.

Interagency Coordination: NSF, NASA, DOE talk regularly about program planning, overlaps, issues
Quarterly DOE-HEP/NSF-PHY meetings.

Project Coordination & Oversight:
Joint Oversight Group (JOG) or Interagency Coordination Group (ICG):
VERITAS, HAWC, DESI, LSST, DES, SuperCDMS-SNOLab; Finance Board meetings: Auger, FGST

International Efforts
- DOE making country-level agreements to allow science partnerships to move forward.
- HEP participating on the Global Science Forum's Astro-particle Physics International Forum (APIF)

Projects & funding types

Construction Projects
- "PED" funds
- Dig a hole; permanent structure

Major Item of Equipment (MIE) Projects
- Build instrumentation (detector) to install in a facility
- LSST, DES, DESI, etc

Critical Decision (CD) Process
-- for project design, fabrication phase

CD-0 – science mission need

CD-1 – alternative selection and preliminary baseline (scope, cost, schedule)

CD-2 – "baseline"

- Set the funding profile to provide the set scope, cost, schedule and deliver the science

CD-3 – full fabrication starts

CD-4 – fabrication completes

Operations/Science
- HEP supports a science collaboration to participate in the project design, fabrication, operations, data processing and plan/execute/deliver science data analysis
- HEP supports post-CD-4 activities -- commissioning, operations, data processing

HEP funding types:

Design, Fabrication and Operations funds support: engineers, techs, computing professionals, computing hardware & services, M&S, spares, supplies, consumables, etc.

Research funds support the scientists on the collaboration to participate in all phases

Cosmic Frontier Status

Dark Energy - Staged program of complementary suite of imaging and spectroscopic surveys to determine its nature

- **BOSS** operations ended in FY14; **eBOSS, DES** continue operations
- ***Large Synoptic Survey Telescope (LSST)*** received CD-3 in August 2015; fabrication started in FY14
- ***Dark Energy Spectroscopic Instrument (DESI)*** received CD-2 in September 2015; long-lead fabrication started in FY15

Dark Matter (direct detection) - Staged program of current & next-generation experiments with multiple technologies to determine the nature of dark matter particles

- Completing operations on current, 1st generation **(DM-G1)** experiments in FY 2016
- Progress continues on **DM-G2** experiments selected by HEP & NSF-PHY (July 2014):
  - **ADMX-G2** is a small project (below MIE) and started at the end of FY14.
  - **LZ** received CD-1/3a approval in May 2015; approved as MIE fabrication start in FY15; CD-2/3b planned for late FY16
  - **SuperCDMS-SNOLab** CD-1 review planned for November 2015

Cosmic-ray, Gamma-ray – ground & space experiments to perform indirect searches for dark matter, test space-time structure & explore particle acceleration mechanisms

- ***Fermi/GLAST, AMS,* and *HAWC*** continue operations
  HAWC gamma-ray observatory began full science operations in early 2015
- DOE operations efforts to complete in FY 2016 for ***VERITAS* and *Auger***

Cosmic Microwave Background (CMB) - Gain insight into the inflationary epoch at the beginning of the universe; probe dark energy and neutrino properties

- ***South Pole Telescope polarization (SPTpol)*** continues operations
- ***SPT-3G*** fabrication funding approved for FY 2015 – 16; partnership with NSF
- Planning continues for a **CMB Stage 4 (CMB-S4)** experiment

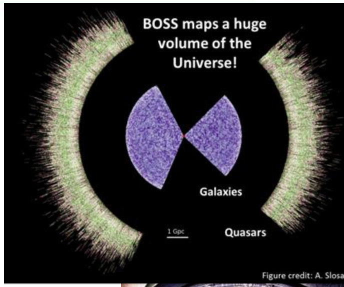
Cosmic Frontier Budget History – details

Cosmic Frontier Budget History ($K)	FY10 Actual	FY11 Actual	FY12 Actual	FY13 Actual	FY14 Actual	FY15 PRB	FY15 Actual	FY16 PRB
Research	**55,487**	**49,252**	**47,843**	**48,652**	**52,712**	**45,435**	**48,779**	**50,079**
Grants	**16,482**	**13,596**	**12,881**	**12,233**	**13,157**	**11,422**	**11,773**	**12,565**
National Laboratories	**39,005**	**35,656**	**34,962**	**36,419**	**39,555**	**34,013**	**37,006**	**37,514**
Facility Operations and Experimental Support	**0**	**7,460**	**8,505**	**10,111**	**10,357**	**7,238**	**9,185**	**7,120**
Projects	**19,828**	**17,652**	**12,891**	**19,159**	**30,660**	**41,000**	**46,403**	**58,701**
MIE	**10,110**	**5,900**	**7,000**	**9,500**	**22,900**	**41,000**	**44,178**	**57,100**
SuperCDMS-Soudan	*1,500*							
DES	*8,610*	*4,000*						
HAWC			*1,500*	*1,500*				
LSSTcamera		*1,900*	*5,500*	*8,000*	*22,000*	*35,000*	*35,000*	*40,800*
DESI							*3,878*	*5,300*
DM-G2					*900*	*6,000*		*11,000*
LZ							*3,050*	
SuperCDMS-SNOLAB							*2,250*	
Small Project Fab + Future R&D	**9,718**	**11,752**	**5,891**					
LSSTcamera	*3,000*	*2,100*						
JDEM, DE future	*6,000*	*3,550*	*2,000*					
Dark Matter G1	*418*	*3,682*	*2,184*					
Dark Matter G2	*300*	*1,600*	*1,000*					
SPTpol		*250*	*429*					
General		*70*	*278*					
HAWC		*500*						
Small Project Fab							**1,025**	**1,601**
ADMX-G2							*925*	
SPT-3G							*100*	
Future R&D				**9,359**	**7,760**		**1,200**	
DESI (BigBOSS)				*2,000*	*1,100*			
Dark Matter G1				*2,200*				
Dark Matter G2				*5,000*	*5,260*			
SPT-3G				*159*	*1,400*		*1,000*	
General							*200*	
TOTAL*	**75,315**	**74,364**	**69,239**	**77,922**	**93,729**	**93,673**	**104,367**	**115,900**

U.S. DEPARTMENT OF ENERGY | Office of Science

***Totals are slightly less than shown in the HEP budget because there are extra funds in each HEP budget line for program reviews & direction, etc.**

Cosmic Frontier Status – Dark Energy

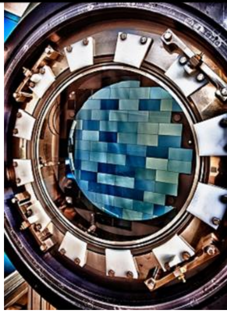


→Staged program of complementary suite of imaging and spectroscopic surveys

P5 recommendation: DESI & LSST

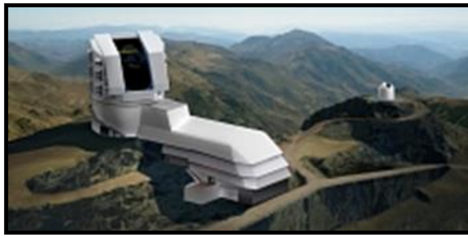
Operating:

- ***BOSS* (spectroscopic) ended in FY14;** final data released & final results out soon
- **eBOSS started in 2015**
- ***DES* (imaging) started 5-year survey in late FY13;** partner with NSF-AST

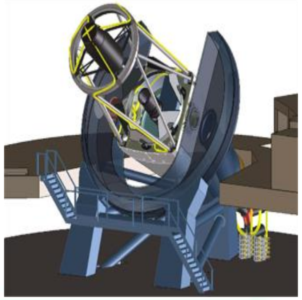


Design, Fabrication:

- ***Large Synoptic Survey Telescope* (LSST, Stage IV imaging)**
  - LSST camera project started fabrication in FY14
  - Partner with NSF-AST (lead agency)
- ***Dark Energy Spectroscopic Instrument* (DESI, Stage IV spectroscopic)**
  - Long-lead fabrication started in FY15
  - Coordination with NSF-AST



Research efforts: In addition to operations, fabrication responsibilities for the above, there are research-only activities on **Euclid, WFIRST, &supernova surveys**

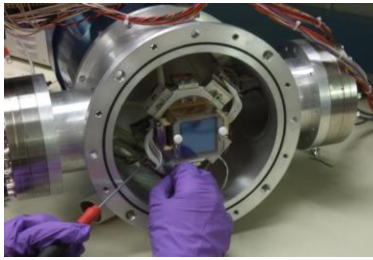


Future planning

- Cosmic Visions Dark Energy (CV-DE) planning group has started

» HEP Community group to coordinate R&D efforts & planning for future data, experiments and projects; develop methods to extract precision measurements from all results

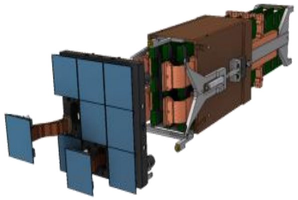
Large Synoptic Survey Telescope (LSST)



Project Description:
- **New 8.4 m telescope facility & associated instrumentation on Cerro Pachon, Chile**

Recommendations/Guidance:
- **Top-ranked large ground-based project in NRC's Astro2010 NWNH report**
- **P5 #17: Complete LSST as planned.**

Physics:
- Optical/NIR imaging all-sky survey with repeated scans of the sky.
- **DOE's interest is in Stage-IV precisions measurements of the nature of Dark Energy, causing the expansion of the universe to accelerate. LSST will provde Stage-IV imaging using multiple cosmological probes including weak lensing.**
- The data will be used by the wider community for a variety of astronomical measurements.

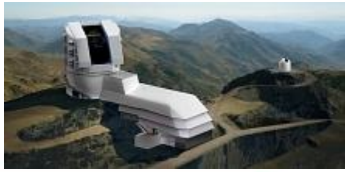


LSST - Science Raft Tower, Part of the DOE deliverables

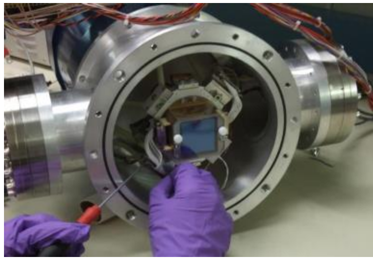
Partnership:
- **DOE-HEP/ NSF-AST partnership**
- NSF is the lead-agency, responsible for telescope facility & data management system
- HEP is responsible for the 3-billion pixel imaging camera (LSSTcamera)
  - SLAC management; major effort by BNL, LLNL, contributions from LBNL, FNAL, universities.
- DOE and NSF-AST MOA describes the roles & responsibilities
- NSF/DOE Joint Oversight Group (JOG) meets weekly, briefs OSTP regularly.

Science Collaboration:

Dark Energy Science Collaboration (DESC) formed to provide science results needed to satisfy DOE; planning & studies for precision analyses.

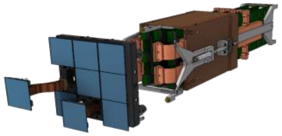


Large Synoptic Survey Telescope (LSST)



Status:
- **Approved in FY14 as MIE project** with long-lead procurements
- CD-2 “baseline” approved Jan 2015
- CD-3 **full fabrication approved** August 2015

LSSTcamera Cost/schedule/funding: Baseline/current status
- Total Project Cost = $168M (~ 31% cost contingency on work-to-go)
- Camera ship to summit in 2QFY20
- CD-4 in 2QFY22

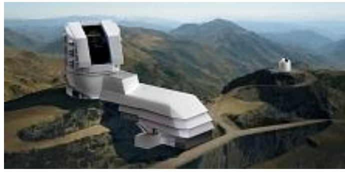


LSST - Science Raft Tower, Part of the DOE deliverables

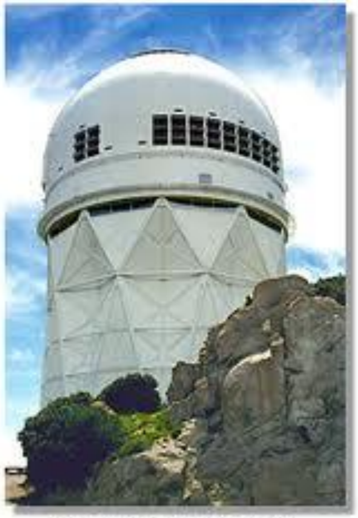
Other costs – not included in LSSTcamera costs, but is being planned
- Support for scientists – continues throughout all phases
- Support for LSSTcamera installation, commissioning, LSST facility operations and DESC collaboration operations.

Planning:
- Discussions with Project, DOE, NSF, laboratories, DESC regarding planning for LSST facility operations and LSST-DESC operations/data analysis.

Recent Highlights:
- Completion of M1M3 mirror (Feb 2015)
- “First Stone” ceremony on Cerro Pachon site (Apr 2015)
- $1M Challenge matching grant from Bill Gates, Charles Simonyi (Jan 2015)



Dark Energy Spectroscopic Instrument (DESI)



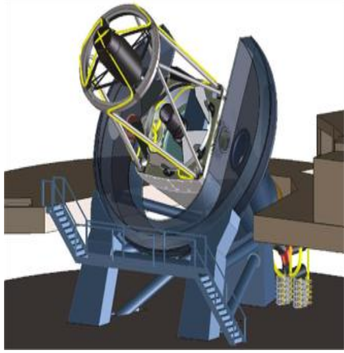
Mayall 4-Meter Telescope

Description:
- Project will fabricate 10 new spectrographs & robotic fiber positioner system to be installed and operated on the existing Mayall 4-m telescope on Kitt Peak.

Recommendations:
- NWNH called it out (BigBOSS) as possibility for mid-scale program (2nd priority ground)
- Rocky-III task force said it would complete a Stage-IV HEP dark energy program.
- P5 recommended DESI in all but the lowest funding scenario.

Physics:
- Stage 4 Dark Energy experiment – spectroscopic survey
- Galaxy clustering redshift survey including Baryon Acoustic Oscillation (BAO) distance & Redshift Space Distortion (RSD) growth methods. Mapping 3-D positions of ~25 million galaxies & line-of-sight to 1.5M quasars using Lyman-alpha forest.
- DESI will complement the DES → LSST imaging surveys.

"HEP experiment" → HEP is fabricating the DESI instrument and supporting instrument & telescope operations to obtain the precision/coordinated science results provided by a science collaboration.



Agency Coordination/Organization
- HEP/LBNL had process to select best facility to host DESI; request to NSF to use the Mayall
- Have DOE+NSF MOA for NOAO operations for the Mayall during the transition period (FY16-18) with HEP ramp-up & NSF ramp-down
- HEP will provide full Mayall costs for dark energy science operations starting in FY19; DOE-NSF MOA in process
- Bi-weekly DOE/NSF Joint Oversight Group (JOG) meetings

Collaborations & Partnerships:
- Scientists from 39 US and international institutions.
- DESI contributions from: DOE, NSF/AST, STFC (UK), France + additional foreign and private contributions, including the Heising-Simons Foundation
- HEP support to LBNL (Project Office) + FNAL, SLAC, ANL, BNL, and 10+ universities

Dark Energy Spectroscopic Instrument (DESI)

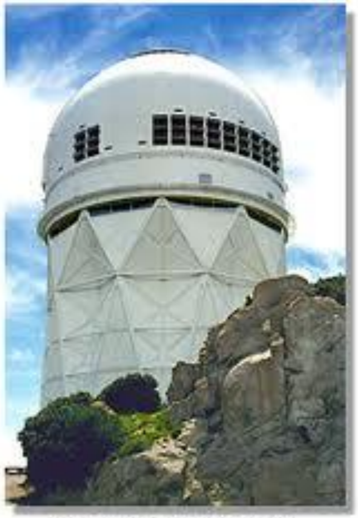
Status:
Approved as an MIE project in FY15; with long lead procurements
CD-2 “baseline” approved in Sep 2015
CD-3 review planned for May 2016

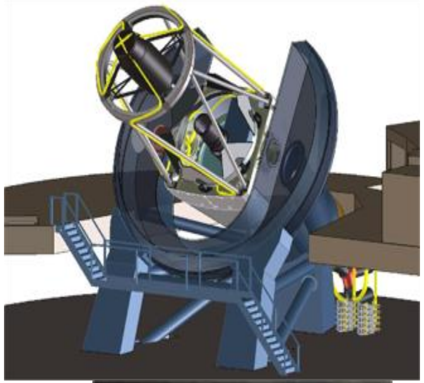
DESI Project Cost/schedule/funding: Baseline/current status
- Total Project Cost = $56.3M (~ 33% cost contingency on work-to-go)
- Mayall shutdown, ready for DESI 1QFY17
- DESI+Mayall commissioning complete 1QFY20
- CD-4 in 4QFY21

Other costs – not included in DESI Project costs, but is being planned
- Support for scientists – continues throughout all phases
- Support for Mayall+DESI dark energy science operations, DESI collaboration operations

Targeting surveys - status
- DESI is supporting wide-area public imaging surveys: DECaLS, BASS, MzLS – combined they expect to cover 14,000 sq deg in 3 bands.
- DOE support for these surveys and for:
    - Upgrade of the NOAO Mosaic camera with LBNL CCD’s and electronics
    - Computing analysis and support & NERSC hours

Data:
- **All data will be made public after appropriate proprietary period** for the DESI collaboration to deliver the required science results to HEP.
- This proprietary period & plan will need to be agreed up on by the agencies.
- DESI will provide a draft operations plan (for the May 2016 CD-3 review) that includes the draft public data release plan.


Mayall 4-Meter Telescope



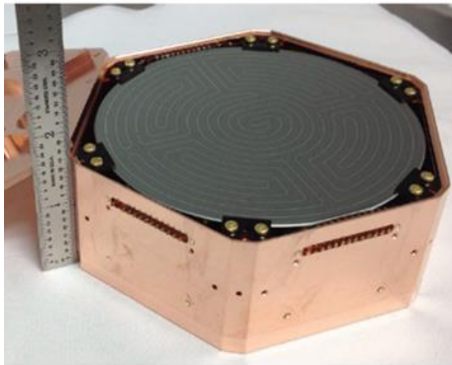
Direct Detection Dark Matter (DDDM)

Learn the particle identity and nature of Dark Matter using direct-detection method
- **Staged program of experiments with multiple technologies & methods**

Operating:
1st generation (DM-G1) experiments: **ADMX, LUX, CDMS-Soudan, DarkSide, COUPP/PICO**

Design, Fabrication:
In July 2014, DOE and NSF-Physics announced selection of Dark Matter Generation 2 (DM-G2) experiments to move forward to fabrication phase:

- **ADMX-G2 (axion search)** is a small project (below MIE) and started at the end of FY14.
- **LZ** (WIMP search) had successful CD-1 review in March 2015; approved as MIE in FY15; CD-2/3b planned for late FY16
- **SuperCDMS-SNOLab** (WIMP search) CD-1 review planned for November 2015



P5: The overall DOE & NSF coordinated DDDM program will need to include DM-G2 project(s), operations of current experiments, background and material studies, and future R&D efforts

- ➢ HEP now concentrating on getting the DM-G2 experiment(s) successfully started
- ➢ FY15/16 – small amount of R&D funding planned; significant R&D or DM-G3 studies assumes adequate funding and will take place later on

LUX

Future planning
Cosmic Visions Dark Matter (CV-DM) planning group being set up soon
- ➢ HEP community group to coordinate R&D efforts and needs, science directions for future small experiments, planning for future DM-G3

Cosmic Frontier – CMB

Gain insight into the inflationary epoch at the beginning of the universe

- **Probe dark energy and neutrino properties by studying the oldest visible light**
- **B mode power spectrum starting to be mapped**

Operating:

– *South Pole Telescope polarization* (SPTpol)
  - HEP provided support for outer-ring detectors

Fabrication:

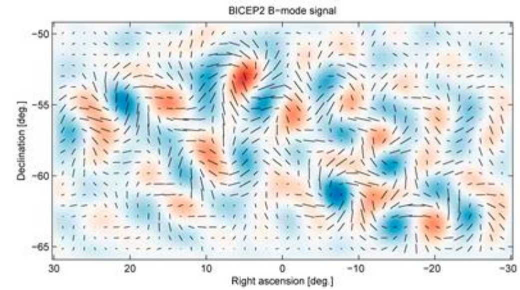
SPT-3G

– major upgrade of the camera to greatly increase sensitivity
– NSF Polar Programs is lead + NSF-PHY, NSF-AST;
– HEP is funding R&D and fabrication phase (FY14-16)

Research efforts: HEP supports research-only activities on BICEP, POLARBEAR and had commitments for research and computing resources for Planck (through NERSC).

Project efforts: Lab-Directed R&D (LDRD) support for project, technology efforts on all these experiments + for future

South Pole Telescope (SPT)



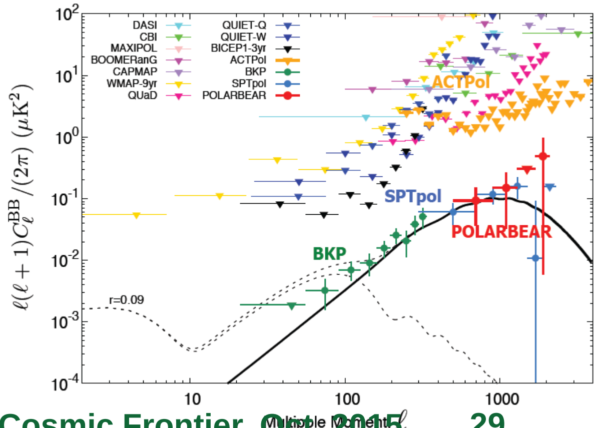
Planck view of BICEP2 field

Future planning

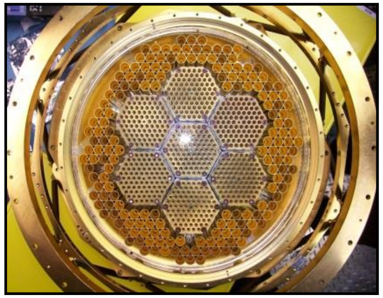
Cosmic Visions CMB-S4 (CV-CMB) planning group is ongoing

- HEP community group to coordinate R&D & planning efforts within HEP

– HEP has started meeting with our labs to oversee coordination of efforts within t HEP program and plan for technical, science studies
– CV-CMB group has written white papers on science, technology & programmatic considerations
– CMB-S4 Collaboration (wider than CV-CMB) is working on a Science Book



HEP CMB Technology – from Stage 1 to Stage 4



Detectors – bolometers, sinuous pixels, multichroic, massive arrays

Electronics – high density interconnectivity

Argonne NATIONAL LABORATORY

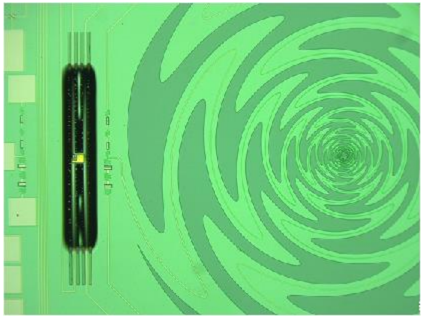
Fermilab

SLAC NATIONAL ACCELERATOR LABORATORY

BERKELEY LAB

Optics – cold optics, lenslets, anti-reflection coatings

Readout – multiplexing, superconducting LC resonators, superconducting NbTi striplines



Cosmic Frontier – Cosmic-ray, Gamma-ray

Use ground-based arrays, space telescopes to

- **Perform indirect searches for dark matter**
- **Test space-time structure (Lorentz invariance)**
- **Explore particle acceleration mechanisms**

Operating/Analysis:

- ***Fermi/GLAST***
  - HEP participation planning in coordination with NASA; HEP expects to support operations for up to a 10 year survey
- ***VERITAS***
  - HEP participation ramping down in FY16
- ***Auger***
  - HEP participation ramping down in FY16
  - no participation planned on upgrade
- ***AMS***
  - operations continuing
- ***HAWC***
  - 5 year operations started early 2015

P5 Recommendation **- Cherenkov Telescope Array (CTA)**

- US Community **developing a plan to** participate in a European-led next generation gamma ray observatory
- HEP response to P5 recommendation, funding availability & programmatic priorities:

  →HEP not continuing support of research, planning, R&D efforts on CTA.

Science Advances 2011-2015

Dark Energy

DES –

- In 3rd season
- Largest weak lensing sky map of dark matter
- Discovery of 17 new Milky Way dwarf galaxy satellite candidates – prime homes for dark matter detection; stringent constraints from joint DES-FGST analysis

BOSS –

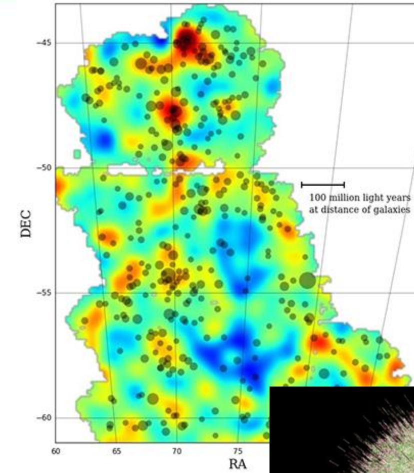
- Completed full survey on time; final data publicly released
- 1-3.5% constraints on distances, Hubble parameter at 3 redshifts
- Successful use of Lyman alpha forest as cosmology probe

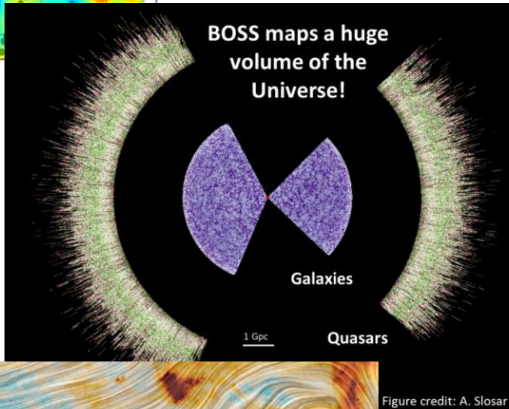
Supernovae –

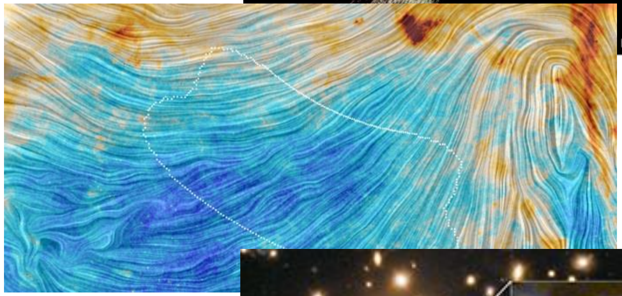
- Joint Lightcurve Analysis (SDSS-SN/SNLS) expansion history
- Supernova-host mass correlation correction to Hubble constant, agreeing with Planck
- First strongly lensed multiple image (Einstein cross) supernova discovered

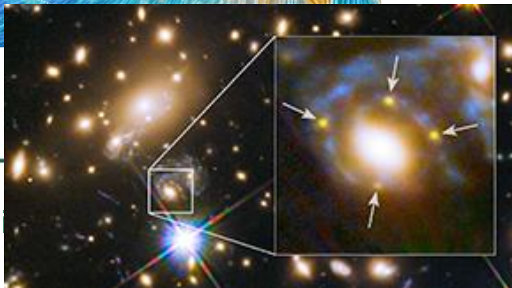
CMB

- CMB lensing detected, used as cosmology probe
- B-mode polarization measured, constraining inflation
- Kinematic Sunyaev-Zel'dovich effect measured









Science Advances 2011-2015

Direct Detection Dark Matter searches with "Generation 1" experiments:

LUX, SuperCDMS, DAMIC and PICO

Significant improvements in previous limit on for both spin-dependent and spin-independent cross WIMP-nucleon cross section.

Indirect Dark Matter searches:

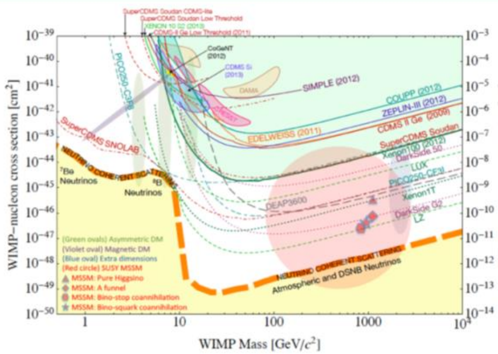
Fermi-LAT, VERITAS, HAWC

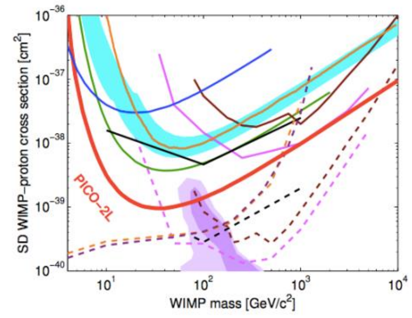
- First exclusion of thermal DM-nucleon cross section consistent with relic density (Fermi)
- Exclusion of DM in 1-10 TeV scale by HAWC

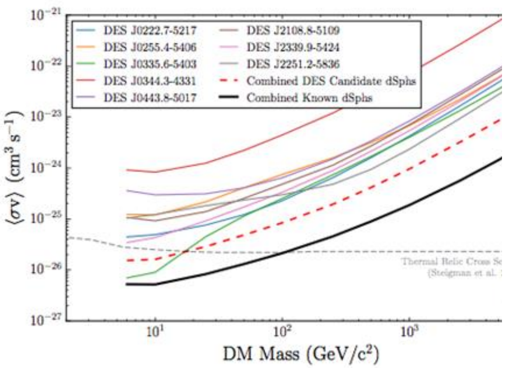
Gamma Ray/Cosmic Rays:

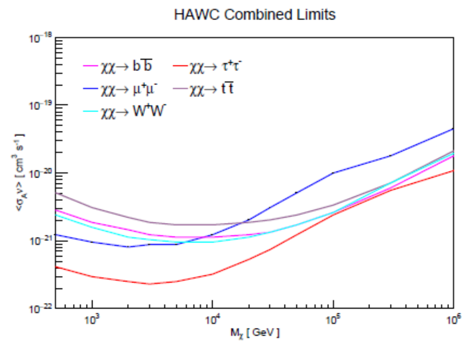
AMS, Auger, Fermi, VERITAS, HAWC

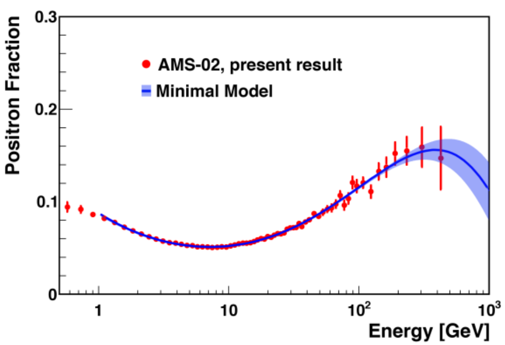
- Leveling off of positron fraction at ~300 GeV reported (Sep 2014) , consistent with either dark matter or pulsar origin. (AMS)
- Observation of anti-proton spectrum up to (AMS)
- VERITAS - Detection of pulsed gamma rays above 100GeV from Crab Pulsar (wasn't expected - reported in Science 2011)
- Origin of Cosmic Rays (Fermi GST) was chosen as one of the Top 10 Science Breakthroughs of the Year by Science magazine (AAAS) (2013)

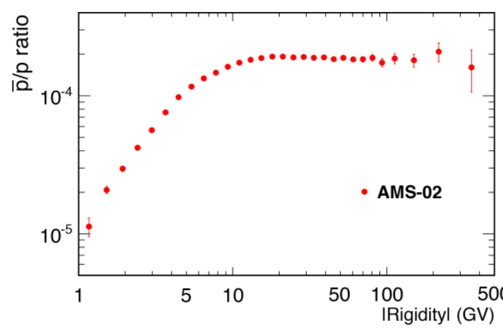




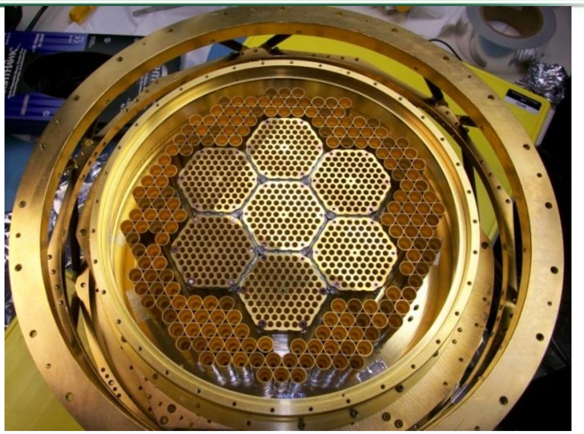


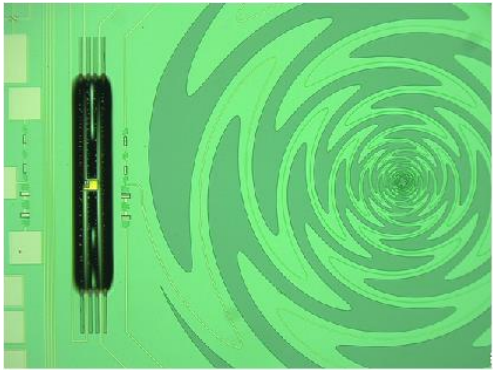


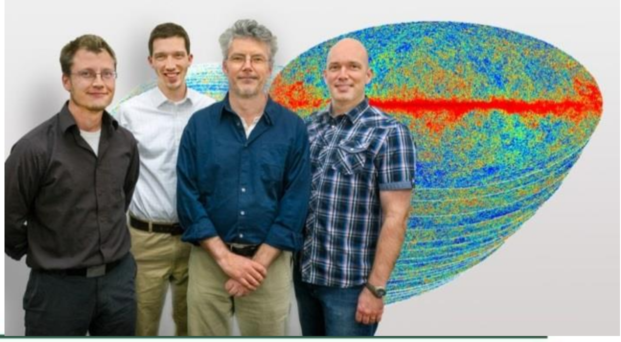




Technology/Computational Advances 2011-2015







Technology:

Fully depleted, low noise, red sensitive CCDs (DES, LSST)

Fabrication of unified primary/tertiary mirror (LSST)

Robotic fiber positioners for massively multiobject spectroscopy (DESI)

High sensitivity, transition edge sensor detector arrays (CMB)

Multichroic polarization sensitive detectors (CMB)

R&D on superconducting quantum-effect sensors (CMB)

Computational:

Trillion particle cosmological simulations (Gordon Bell Prize supercomputing finalists 2012, 2013)

Cosmology emulators to 1% in matter power spectrum, halo mass function

Planck full sky map simulations

HEP MOU with NASA for Planck analysis – in 2014, 100M CPU-hours, NERSC Achievement Award for High-Impact Science

Technology Advances 2011-2015

Technology:

Successful operation of Liquid Xenon TPC, new calibration and veto techniques system (LUX/LZ)

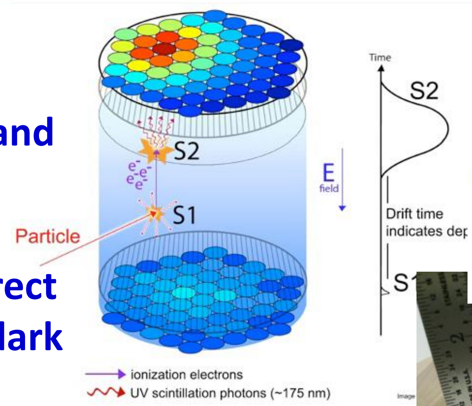
Achievement of ultra-low energy thresholds (< 50 eV) in direct detection experiments, providing access to very low mass dark matter particles. (SuperCDMS and DAMIC)

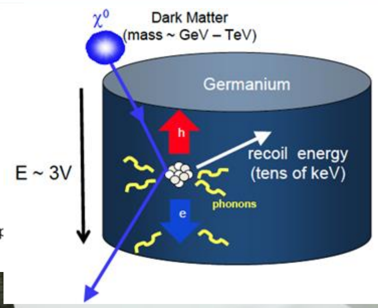
Operation of a liquid argon TPC as a dark matter search using argon with very low radioactivity.

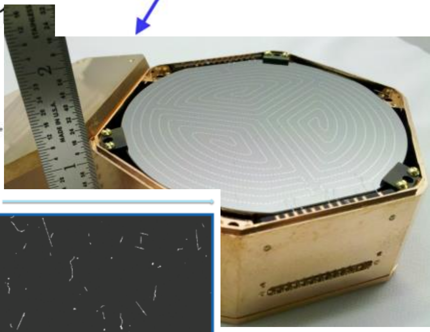
Operation of a bubble chamber for a dark matter search using a new fluid (C3F8) optimized to detect spin-dependent WIMP interactions.

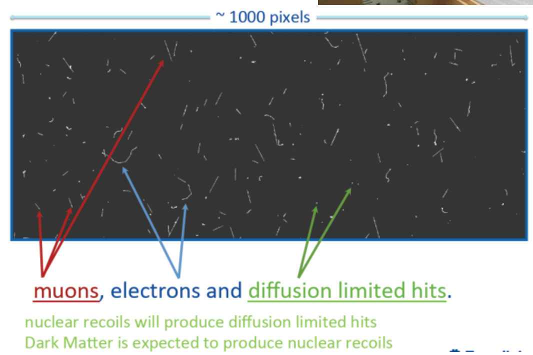
Operations of 300-tank HAWC, ground based Water Cherenkov Gamma ray detector began April 2015.

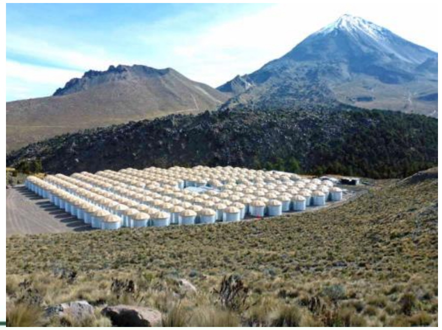
Upgrade of VERITAS to achieve lower detection threshold.











Prizes, Awards

2015

Gruber Cosmology Prize – John Carlstrom
Cosmic Microwave Background; together with Jeremiah Ostriker and Lyman Page.

E.O. Lawrence Prize – David Schlegel; Galaxy redshift surveys, e.g. Baryon Oscillation Spectroscopic Survey.

2014

Breakthrough Prize in Fundamental Physics – Saul Perlmutter & Supernova Cosmology Project
Cosmic Acceleration; together with Adam Riess, Brian Schmidt.

Rossi Prize – Doug Finkbeiner, Tracy Slatyer, Meng Su ; Fermi bubbles

2013

Panofsky Prize – Blas Cabrera, Bernard Sadoulet; Direct detection dark matter techniques.

Gordon Bell Prize (supercomputing) finalists – Salman Habib, Katrin Heitmann, & team; Cosmological simulations.

2012

Panofsky Prize – William Atwood; Large Area Telescope, Fermi Gamma Ray Space Telescope.

Gordon Bell Prize (supercomputing) finalists – Salman Habib, Katrin Heitmann, & team; Cosmological simulations.

2011

Nobel Prize in Physics – Saul Perlmutter Cosmic Acceleration; together with Adam Riess, Brian Schmidt.
Rossi Prize – William Atwood, Peter Michelson & FGST/LAT Team; Large Area Telescope, Fermi Gamma Ray Space Telescope.

Science of the Year

2014

Physics World – Top Ten

Mapping the cosmic web with the Lyman alpha forest.

Scientific American – #4 Science Story of the Year

Cosmic Microwave Background B-mode polarization large angle measurements by BICEP.

Nature Magazine – Top Stories

Cosmic Microwave Background B-mode polarization large angle measurements by BICEP.

Discovery Magazine – #5 Science Story of the Year

Cosmic Microwave Background B-mode polarization large angle measurements by BICEP.

2013

Physics World – Top Ten

South Pole Telescope detection of Cosmic Microwave Background B-mode polarization.
Planck satellite measurements of Cosmic Microwave Background anisotropies.

Science News – #3 Story of the Year

Planck satellite measurements of Cosmic Microwave Background anisotropies.

Science Magazine - Top 10 Science Breakthroughs of the Year

Origin of Cosmic Rays by Fermi Gamma Ray Space Telescope.

Nature Magazine – Story of the Year

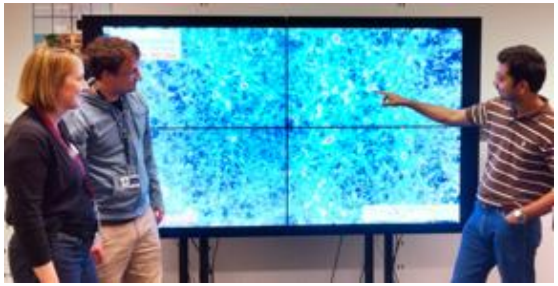
Direct detection dark matter limits by LUX.

2012

Physics World – Top Ten

Kinematic Sunyaev-Zel'dovich effect detected.

Theory and Computational Cosmology



Theory

- Vibrant Theory Program supporting all areas including Cosmic Frontier.
- Support for Theory centers and groups at several universities and labs.
  - No planning for a separate Cosmic Theory program

High Performance Computing:

- HEP Computational Program (Comp HEP) provides direct funding
- Comp HEP & ASCR coordination & partnerships on some efforts, including Cosmic Simulation and Data analytics

Comp HEP

- Coordinates DOE Supercomputer allocations via various ASCR and DOE Competitions
- Manages allocations on NERSC facility for HEP Cosmic Frontier Simulations and Experiments

Efforts:

- Cosmic Simulations, Emulators, Data Analysis
- Computational HEP, SCIDAC (Scientific Discovery through Advanced Computing) – focused computational challenges
- HEP Forum for Computational Excellence

NERSC Allocations 2015:

– Total HEP Target Plus OT: 340 M Hours (expected to triple by 2018)

– Cosmic Frontier related is ~ 40% of this.

NERSC: used for analysis of many CMB experiments: in 2014 ~10 experiments with ~100 users, with ~10M CPU-hours

NERSC: HEP MOU with NASA for Planck analysis – in 2014, 100M CPU-hours.

Detectors, Data

Advanced Detector Development

- Active R&D developing next generation detectors, including CCDs, TES superconducting bolometers, MKIDs, readout electronics, optics. Key elements for DES, LSST, CMB-S4. Important impact on X-ray detector, medical detectors.

- Laboratory funded R&D

- This week: APS Coordinating Panel for Advanced Detectors “Instrumentation Frontier” meeting.

Data

Following:

- DOE-SC Digital Data Management requirements (requirements on published data)
- AAAC Principles for Astrophysics projects

Data Management Plans

- Each Project/Experiment has provided a summary-level Data Management Plan to HEP
- Used for referencing in research proposals; also to check against *AAAC Principles for Access in Astrophysics* and *SC Statement on Digital Data Management*

Tri-Agency Group (TAG)

Monthly meetings of Agency program managers together with US leads on LSST, WFIRST, Euclid to discuss commonalities, coordination

Cosmic Visions – looking towards the future

Cosmic Visions groups have been set up

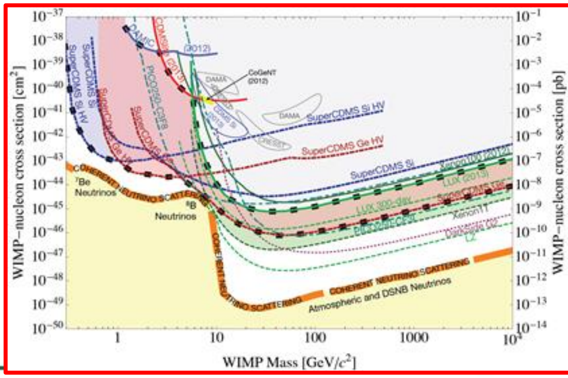
- **Community groups that will collect, coordinate HEP community status, R&D effort, planning, studies & options for future datasets, experiments, projects**
  - Follow on from Snowmass, P5
  - Can inform next Decadal survey
- **Regular meetings with HEP**

CV-CMB

- CMB-S4 to probe inflation with ~0.5 million detectors.
- HEP & larger community planning underway
- HEP has started meeting with our labs to coordination of efforts within the HEP program and plan for technical, science studies

CV-DE

- Plan future directions in dark energy research, datasets, experiments, or facilities following the end of construction of DESI and LSST.
- "Complement, build upon, and extend beyond these experiments in investigating the physics of dark energy."



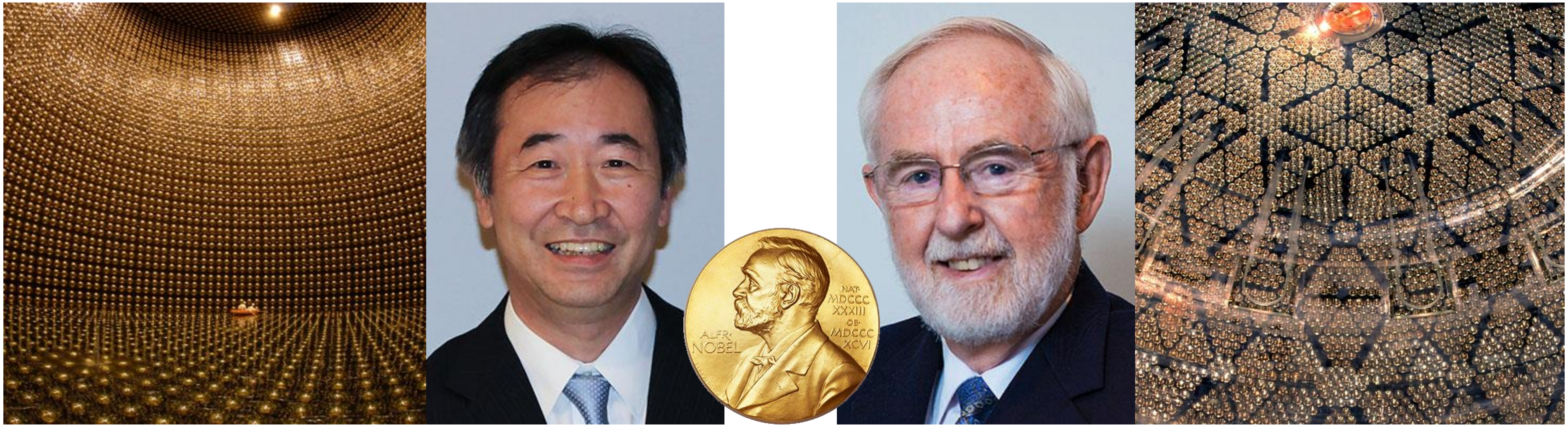
CV-DM

- R&D to investigate technologies and G3 experiments
- coordinate R&D efforts, background and calibration study needs, science directions for future small experiments, planning for future DM-G3

U.S. DEPARTMENT OF ENERGY | Office of Science

2015 Nobel Prize in Physics

The Nobel Prize in Physics for 2015 was awarded to Takaaki Kajita and Arthur B. McDonald for the discovery of neutrino oscillations, which shows that neutrinos have mass.



- The DOE Office of Science helped enable the discovery of neutrino oscillation by providing substantial support to the construction, operation, and research efforts of the Super-Kamiokande experiment in Japan and the Sudbury Neutrino Observatory in Canada
- The DOE High Energy Physics program is actively pursing the physics associated with neutrino mass through the Cosmic Frontier (DESI, LSST, CMB-S4) and the Intensity Frontier (including a coherent set of U.S.-hosted, international short- and long-baseline neutrino experiments).

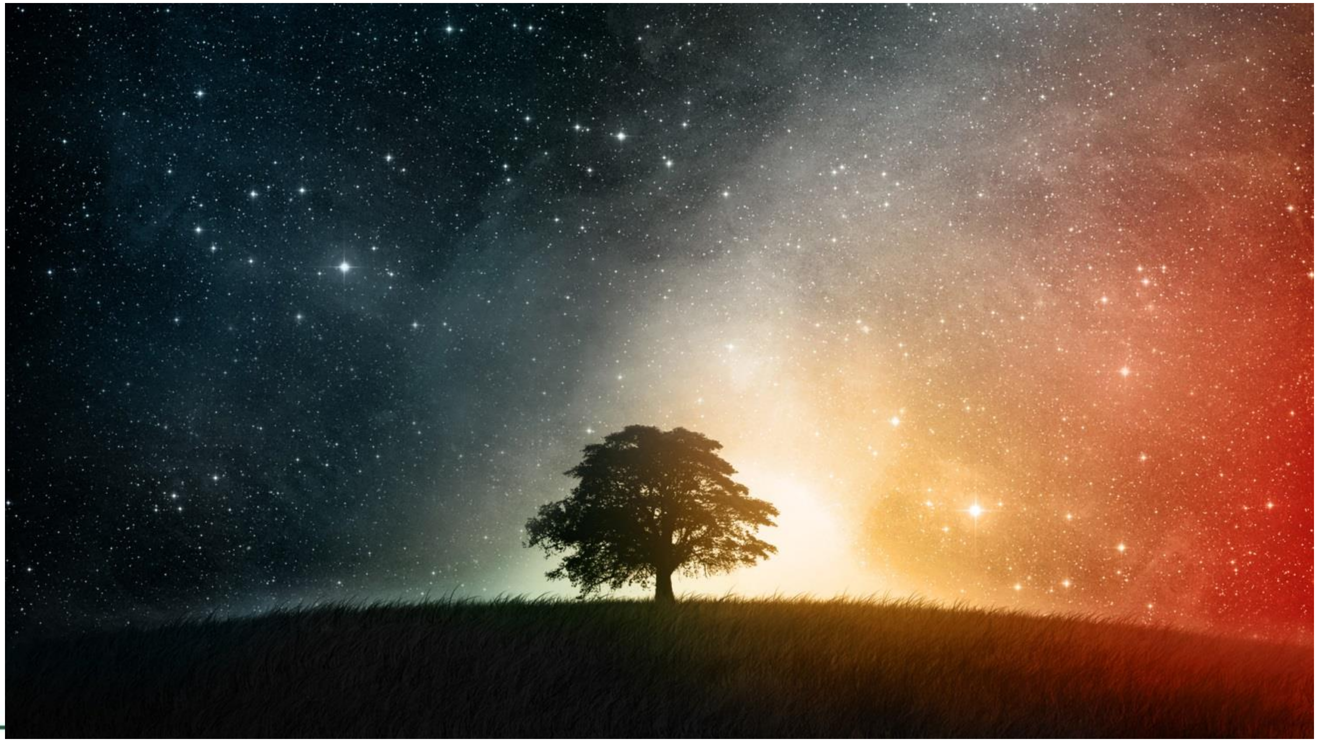
Summary

- **An exciting time for HEP and the Cosmic Frontier!**

- **P5 developed compelling, realistic strategic plan with a consensus vision for US HEP**

→HEP is moving forward to implement it.

- **Close coordination with the other agencies.**



BACKUPS

Cosmic Frontier
Guidance from Astro2010 "New Worlds New Horizons" Report (August 2010)

Recommendation – International Collaborations (World-wide Open-skies policy):
U.S. investors in astronomy and astrophysics, both public and private, should consider a wide range of approaches to realize participation in international projects and to provide access for the U.S. astronomy and astrophysics community to a larger suite of facilities than can be supported within the United States. The long-term goal should be to maximize the scientific output from major astronomical facilities throughout the world, a goal that is best achieved through opening access to all astronomers. These could include not only shared construction and operation costs but also strategic timesharing and data-sharing agreements.

Recommendation - International Coordination/cooperation:
Approximately every 5 years the international science community should come together in a forum to share scientific directions and strategic plans, and to look for opportunities for further collaboration and cooperation, especially on large projects.

Recommendation - Stewardship :
NASA, NSF, and DOE should on a regular basis request advice from an independent standing committee constituted to monitor progress toward reaching the goals recommended in the decadal survey of astronomy and astrophysics, and to provide strategic advice to the agencies over the decade of implementation.

Recommendation - Research Networks in Theoretical and Computational Astrophysics
A new program of Research Networks in Theoretical and Computational Astrophysics should be funded by DOE, NASA, and NSF. The program would support research in six to eight focus areas that cover major theoretical questions raised by the survey Science Frontier Panels.
NASA/DOE: To enable the large-scale theoretical investigations identified as science priorities by this survey, the committee proposes a new competed program to support coordinated theoretical and computational research—particularly that of fundamental relevance to upcoming space observatories. For NASA an annual budget of $5 million is recommended. For DOE an annual funding level of $1 million is recommended for activities related to space-based research.
NSF/DOE: This is a new competed program coordinated between NSF and DOE to support coordinated theoretical and computational attacks on selected key projects that are judged ripe for such attention. An NSF annual funding level of $2.5 million is recommended. For DOE an annual funding level of $1 million is recommended. A similar program is proposed for NASA and DOE above in the space-based program recommendations.

Recommendation - Data Handling
Proposals for new major ground-based facilities and instruments with significant federal funding should be required as a matter of agency policy to include a plan and if necessary a budget for ensuring appropriate data acquisition, processing, archiving, and public access after a suitable proprietary period.

Recommendation - Stewardship - Data Curation
NSF, NASA, and DOE should plan for effective long-term curation of, and access to, large astronomical data sets after completion of the missions or projects that produced these data, given the likely future scientific benefit of the data. NASA currently supports widely used curated data archives, and similar data curation models could be adopted by NSF and DOE.

Guidance from Astro2010 "New Worlds New Horizons" Report (August 2010)

Specific Recommendations to DOE :

A program fitted under the **DOE budget doubling scenario** means that roughly $40 million per year would be available by the end of the decade, after due allowance for an underground dark matter detection program as recommended by HEPAP-PASAG. This amount will be sufficient to allow participation in LSST, WFIRST, and ACTA as well as some of the smaller astrophysical initiatives recommended by HEPAP-PASAG under Scenario C. In addition, a $2 million per year Theory and Computation Networks program is recommended.

However, **if the budget is lower**, the HEPAP-PASAG recommended investment in dark matter detection will be reduced and the available funds will decrease to $15 million under Scenario A. DOE is a minor partner in the two largest projects that the survey committee has recommended—LSST and WFIRST—and it is likely that the phasing will involve choices by NSF and NASA, respectively. Other considerations being equal, the recommended priority order is to collaborate first on LSST because DOE will have a larger fractional participation in that project, and its technical contribution is thought to be relatively more critical. ACTA, Theory and Computation Networks, and the smaller initiatives have lower priority.

Summary: In lower scenarios, DOE should participate in LSST ahead of WFIRST since DOE is making a larger relative $ contribution and its technical role is thought to be relatively more critical. DOE may have opportunities to contribute to mid-scale ground-based projects with NSF (ground priority #2), and should contribute to ACTA with NSF and to the Theory & Computation Network (TCN). These smaller programs and ACTA have lower priority than LSST & WFIRST.

P5 Report – Program & Project Criteria

HEP will use P5 criteria to develop the program and determine which projects, and at what level, to invest in.

- **Program optimization criteria**

– **Science**: based on the Drivers, assess where we want to go and how to get there, with a portfolio of the most promising approaches.
– **International context**: pursue the most important opportunities wherever they are, and host world-leading facilities that attract the worldwide scientific community; duplication should only occur when significant value is added or when competition helps propel the field in important directions.
– **Sustained productivity**: maintain a stream of science results while investing in future capabilities, which implies a balance of project sizes; maintain and develop critical technical and scientific expertise and infrastructure to enable future discoveries.

- **Individual project criteria**

– **Science:** how the project addresses key questions in particle physics, the size and relevance of the discovery reach, how the experiment might change the direction of the field, and the value of null results.
– **Timing**: when the project is needed, and how it fits into the larger picture.
– **Uniqueness**: what the experiment adds that is unique and/or definitive, and where it might lead. Consider the alternatives.
– **Cost vs. value**: the scope should be well defined and match the physics case. For multidisciplinary/agency projects, distribution of support should match the distribution of science.
– **History and dependencies**: previous prioritization, existing commitments, and the impacts of changes in direction.
– **Feasibility**: consider the main technical, cost, and schedule risks of the proposed project.
– **Roles**: U.S. particle physics leadership

May 2014 P5 Report – Cosmic Frontier Recommendations

Dark Energy - Precision measurements to differentiate between Cosmological Constant, new fields or modification to General Relativity

- P5 #17: Complete LSST as planned.
- P5 #16: Build DESI as a major step forward in dark energy science, if funding permits
  - DESI should be the last project cut if budgets move from Scenario B to Scenario A (lowest)

Dark Matter (Direct Detection) - Learn the identity and nature of Dark Matter

- P5 #19: Proceed immediately with a broad second-generation (G2) dark matter direct detection program with capabilities described in the text. Invest in this program at a level significantly above that called for in the 2012 joint agency announcement of opportunity.
- P5 #20: Support one or more third-generation (G3) direct detection experiments, guided by the results of the preceding searches. Seek a globally complementary program and increased international partnership in G3 experiments.
  - (DM-G3 Project is in the P5 plan later in the decade.)

Cosmic-ray, Gamma-ray Astrophysics - Explore particle acceleration mechanisms and perform indirect searches for dark matter candidates

P5 #21: Invest in CTA as part of the small projects portfolio if the critical NSF Astronomy funding can be obtained.

P5 comments:

- CTA has a broad science reach that transcends fields, with the dark matter detection capabilities of direct importance to particle physics
- Using P5 Criteria, a de-scoped US component should be shared by NSF-AST, NSF-PHY and DOE.

CMB - Gain insight into **inflationary epoch** at the beginning of the universe, **dark energy,** and **neutrino properties** by studying the oldest visible light.

P5 #18: Support CMB experiments as part of the core particle physics program. The multidisciplinary nature of the science warrants continued multi-agency support. (CMB-S4 Project is in the P5 plan later in the decade.)

Cosmic Frontier
Statistics on Comparative Review Research (University) Grants

				FY12	FY13	FY14	FY15
Cosmic CR – $M request (Y1)				$3.3	$7.7	$7.5	$6.8
Cosmic CR – $M funded (Y1)				$1.6	$3.4	$4.4 w/FFF	$3.3 w/FFF
Cosmic CR - proposal counts							
		#proposals	received	11	33	29	27
		#proposals	reviewed	10	28	28	27
		#proposals	funded	6	18	19	14
		#proposals	**success rate**	**60%**	**64%**	**68%**	**52%**
Cosmic CR - PI counts							
		#PI's	received	21	61	40	43
		#PI's	reviewed	20	54	38	43
		#PI's	funded	13	27	25	21
		#PI's	**success rate**	**65%**	**50%**	**66%**	**48%**

Funding:

- Typically the total of all requests is for ~ twice the funds we have available.
- We typically fund the grants at less than their request.
- FY15 Cosmic requests $21.9M (for full grant period) and $6.8M for Year1.

Cosmic Frontier – Statistics on Early Career Grants (Labs & Universities)

	FY10	FY11	FY12	FY13	FY14	FY15
# received - Univ	11	8	12	16	6	7
# received - Lab	10	4	7	9	7	5
# funded - Univ	**2**	**1**	**2**	**1**	**1**	**0**
# funded - Lab	**0**	**2**	**1**	**1**	**0**	**0**

Awards (5-year):

FY10
Newman (Pitt)
Mahapatra (TAMU)

FY11
Chou (FNAL)
Slosar (BNL)
Hall (Maryland)

FY12
Mandelbaum (CMU)
Padmanabhan (Yale)
Carosi (LLNL)

FY13
Bolton (Utah)
Chang (ANL)

FY14
Dahl (Northwestern)

FY15 Review Data — by Proposal

For the FY 2015 cycle, 153 proposals requesting support totaling $221.88M in one or more of the 6 HEP subprograms were received. Of these, 146 were reviewed.

	HEP Subprogram						HEP Total
	Energy	Intensity	Cosmic	Theory	Acc. R&D	Det. R&D	
Received	27	30	27	43	35	24	146
Declined w/o Review	2	0	0	0	2	3	7
Reviewed	25 (6)	30 (9)	27 (17)	43 (17)	33 (20)	21 (11)	139 (79)
Funded	19 (3)	19 (3)	14 (7)	27 (3)	7 (1)	9 (2)	63 (16)
Declined	6 (3)	11 (6)	13 (10)	16 (14)	24 (19)	12 (9)	72 (61)
"Success Rate" (%) (Previous/New)	76	63	52	63	21	43	45 (78/20)

NOTES:
- Single proposals with multiple research thrusts are counted multiple times [1 /thrust]
- ( ) indicates # proposals from research PI/groups that did not receive DOE HEP funding in FY14.
- "Success Rate" is = # Funded/ # Reviewed.
- Most proposals are not fully funded at their "requested" level.
- About 43% of the proposals reviewed were from research groups that received HEP funding in FY14.
- FY15 overall success rate of reviewed proposals for previously (newly) funded groups was 78% (20%).
- Total grant awards funded in FY15 at $32.95M [= 24.48M 'renewal' + 8.47M 'new' proposals]

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Alan Stone

International Agreements Program
Michael Salamon

Accelerator Stewardship
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Michael Zisman (Detailee)

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HEP Connections
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Intensity Frontier
Glen Crawford (Acting)

Cosmic Frontier
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Anwar Bhatti (IPA)
Eric Linder (IPA)

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William Kilgore (Detailee)

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Vera Bibbs

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Fermilab Complex
John Kogut

LHC Operations
Abid Patwa
Simona Rolli

Other Operations [SLAC/Other Labs]
John Kogut

Facilities Development

LARP
Bruce Strauss

Muon Accelerator (MAP)
Bruce Strauss

Instrumentation & Major Systems

NOvA – Ted Lavine
MicroBooNE – Ted Lavine
Mu2e – Ted Lavine
Muon g-2 – Ted Lavine
LBNF – Bill Wisniewski (Detailee)
PIP-II – Steve Peggs (Detailee)
APUL – Bruce Strauss
CMS Upgrade – Simona Rolli
ATLAS Upgrade – Simona Rolli
Belle-II – Helmut Marsiske
LSSTcam – Helmut Marsiske
DESI – Kathy Turner
LZ – Helmut Marsiske
SuperCDMS-SNOLAB – Helmut Marsiske

HEP Cosmic Frontier Program – Science Collaboration Traditions, Priorities

HEP Tradition - Science Collaborations

- We encourage and support scientific teams with expertise in required areas to participate in all phases of a project/experiment, from design to data analysis, in order to produce the best possible science results
  - Scientists work with team of engineers, technical support, computing professionals needed to design, construct and operate the projects.
- Scientists at labs and universities have long term commitments, responsibilities on the projects & experiments, in addition to data analysis, to bring all the tools needed to accomplish the science
- Long term support (funding) is needed to support long term responsibilities (so that projects/experiments can count on the effort)
- Science planning is expected throughout all phases to end up with coordinated data analysis by a collaboration (1 precision result rather than 100 independent results)

Priorities for support

Mission-driven → Need to sufficiently support the science collaborations and project teams to carryout our project's design, fabrication and operations & to plan and carry out data analyses to deliver the best science results.

- *Once our projects/responsibilities are adequately supported, we can consider adding to support or making contributions to projects not in our program*

Leave some room:

- Ensure some room in the research program for development of ideas for new projects that are aligned with the science drivers.
- Research efforts on projects that are aligned with P5 science drivers, but which don't have HEP participation, will also be considered, taking into account the above and based on funding availability.

HEP Cosmic Frontier Program Experiments – current, planned

Activity	Location	Science	Current Status	# Collaborators (# US, HEP)	# Institutions (# US, HEP)	Countries	Partners
Baryon Oscillation Spectrosopic Survey (BOSS)	APO in New Mexico	dark energy stage III (spectroscopic)	operations ended in FY14	230 (150 US, 40 HEP)	(22 US, 8 HEP)	7	NSF-AST
extended BOSS (eBOSS)	APO in New Mexico	dark energy stage III (spectroscopic)	HEP support for operations started FY15				
Dark Energy Survey (DES)	CTIO in Chile	dark energy stage III (imaging)	operations started Sept. 2013	300	25 (13 US, 9 HEP)	6	NSF-AST
Large Synoptic Survey Telescope (LSST) - Dark Energy Science Collaboration (DESC)	Cerro Pachon in Chile	dark energy stage IV (imaging)	science studies, planning	232 (200 US, 134 HEP)	53 (41 US, 16 HEP)	3	NSF-AST
Large Synoptic Survey Telescope (LSST) - LSSTcam Project	Cerro Pachon in Chile	dark energy stage IV (imaging)	FY14 Fab. start; CD2 Jan 2015; CD3 Aug 2015	142 (111 US, 111 HEP)	17 (11 US, 11 HEP)	2	NSF-AST
Dark Energy Spectroscopic Instrument (DESI)	KPNO in AZ (plan)	dark energy stage IV (spectroscopic)	FY15 fab start approved; CD2 approved Sept 2015	179 (93 US, 74 HEP)	39 (21 US, 19 HEP)	9	NSF-AST, STFC (UK)
DM-G1: Axion Dark Matter eXperiment (ADMX-IIa)	Univ Washington	dark matter - axion search	Operating thru 2015	24 (20 US, 17 HEP)	7 (6 US, 3 HEP)	2	
DM-G1: Chicagoland Observatory for Underground Particle Physics (COUPP/PICO)	SNOLab in Canada	dark matter - WIMP search	operating	60 (26 US, 8 HEP)	14 (6 US, 1 HEP)	5	NSF-PHY, Canada
DM-G1: DarkSide-50	LNGS in Italy	dark matter - WIMP search	operating	146 (52 US, 10 HEP)	32 (14 US, 2 HEP)	7	NSF-PHY, INFN
DM-G1: Large Underground Xenon (LUX)	SURF in South Dakota	dark matter - WIMP search	operating	102 (86 US, 64 HEP)	18 (15 US, 13 HEP)	3	NSF-PHY, UK, Portugal
DM-G1: Super Cryogenic Dark Matter Search (SuperCDMS-Soudan)	Soudan in Minnesota	dark matter - WIMP search	operating	83 (72 US, 44 HEP)	20 (17 US, 7 HEP)	3	NSF-PHY, Canada, Spain
DM-G2: ADMX-G2	Univ Washington	dark matter - axion search	fabrication started end FY14	31 (29 US, 20 HEP)	8 (7 US, 4 HEP)	2	UK
DM-G2: SuperCDMS-SNOLAB	SNOLab in Canada	dark matter - WIMP search	CD1 review planned Q1FY16	90 (74 US, 47 HEP)	22 (17 US, 7 HEP)	5	NSF-PHY, Canada, France, UK,Spain
DM-G2: LZ	SURF in South Dakota	dark matter - WIMP search	FY15 fab start; CD1 April 2015; CD2/3b review 2016	154 (118 US, 107 HEP)	28 (18 US, 17 HEP)	3	UK, Russia, Portugal
SPT-polarization (SPT-pol)	South Pole	CMB stage 2	operating	66 (54 US, 8 HEP)	23 (7 US,4 HEP)	5	NSF, Canada
SPT-3G	South Pole	CMB stage 3	HEP fabrication start in FY15	66 (54 US, 8 HEP)	23 (7 US, 4 HEP)	5	NSF, Canada
Very Energetic Radiation Imaging Telescope Array System (VERITAS)	FLWO in AZ	gamma-ray survey	operating	109 (76 US, 28 HEP)	20 (16 US, 5 HEP)	4	NSF, Smithsonian, Ireland, Canada, Germany
Pierre Auger Observatory	Argentina	cosmic-ray	operating (2014 PO moved from FNAL to Germany)	436 (61 US, 18 HEP)	90 (17 US, 6 HEP)	17	All
Fermi Gamma-ray Space Telescope (FGST) Large Area Telescope (LAT)	space-based	gamma-ray survey	June 2008 launch; operating	362 (153 US, 58 HEP)	115 (38 US, 3 HEP)	22	NASA, Italy, France
Alpha Magnetic Spectrometer (AMS-02)	space-based (on ISS)	cosmic-ray	May 2011 launch; operating	600	60 (6 US, 2 HEP)	16	
High Altitude Water Cherenkov (HAWC)	Mexico	gamma-ray survey	Full science operations started early 2015	111 (54 US, 8 HEP)	28 (17 US, 3 HEP)	2	NSF-PHY, Mexico